March 8, 1966 K. S. KELLEHER 3,239,838

DIPOLE ANTENNA MOUNTED IN OPEN-FACED RESONANT CAVITY

Filed May 29, 1963 2 Sheets-Sheet 1

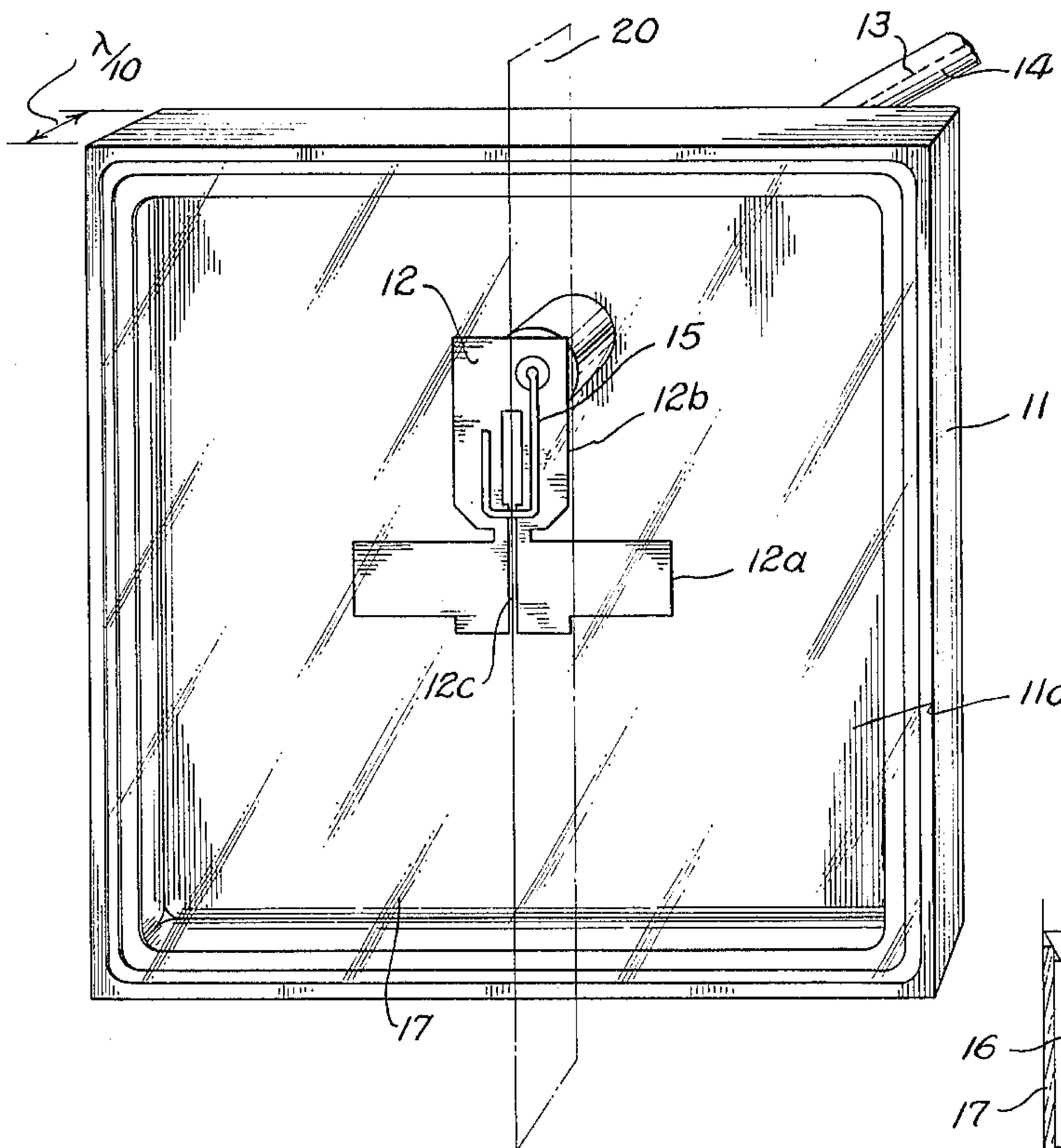

Fig. 1

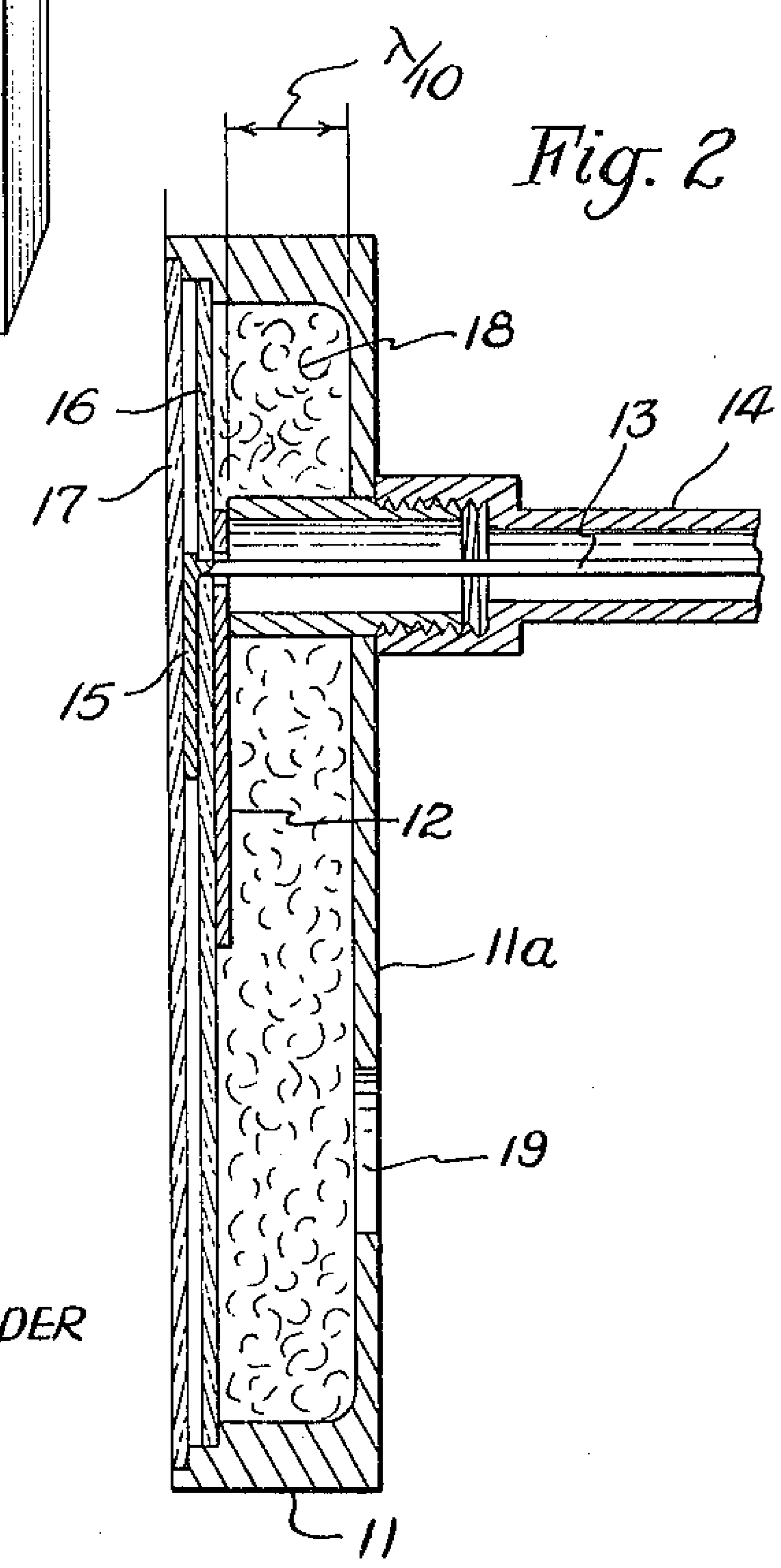

Fig. 2

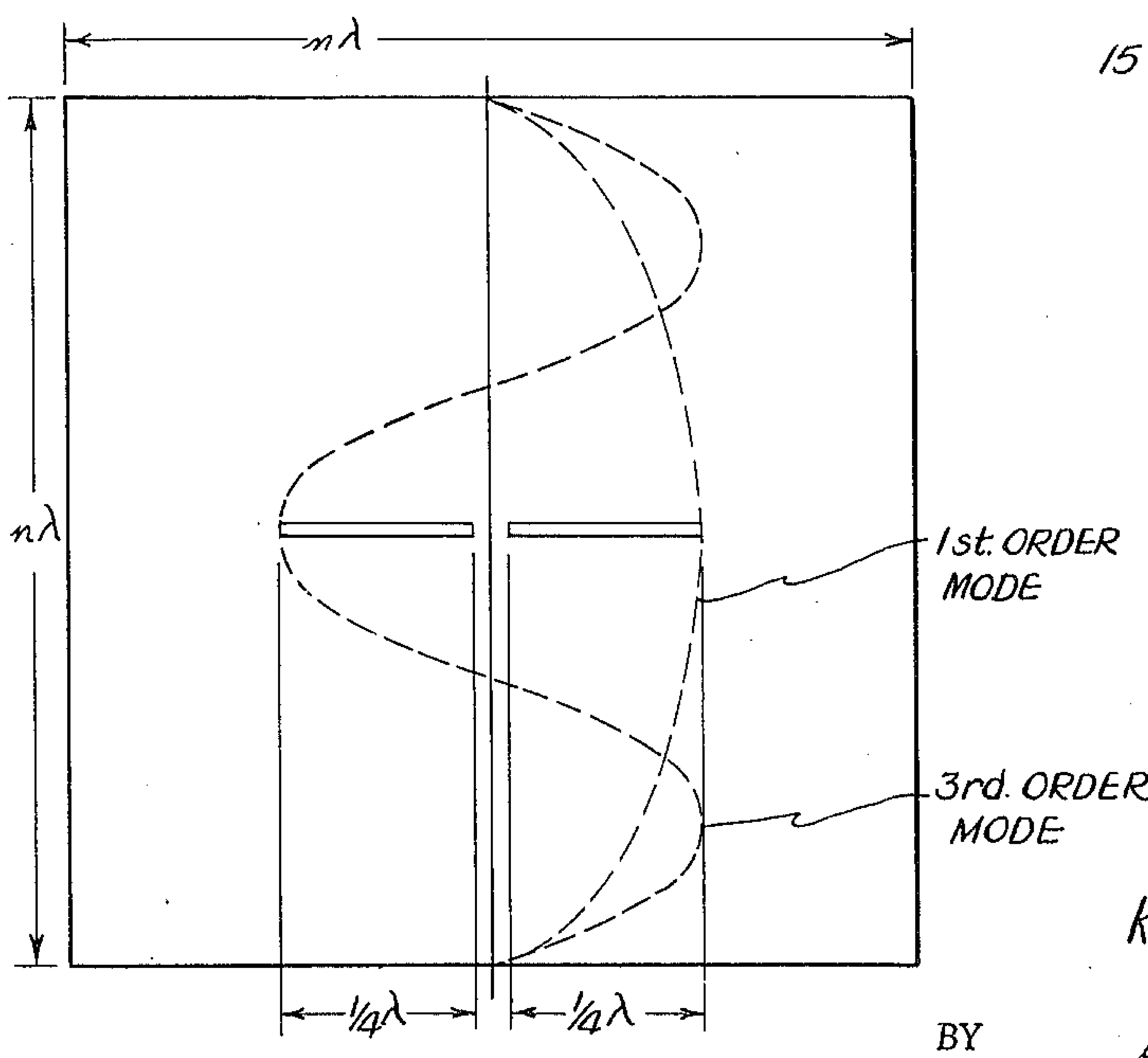

Fig. 3

INVENTOR

Kenneth S. Kelleher

BY Glenn S. Ovrevik

AGENT

DIPOLE ANTENNA MOUNTED IN OPEN-FACED RESONANT CAVITY

Filed May 29, 1963 2 Sheets-Sheet 2

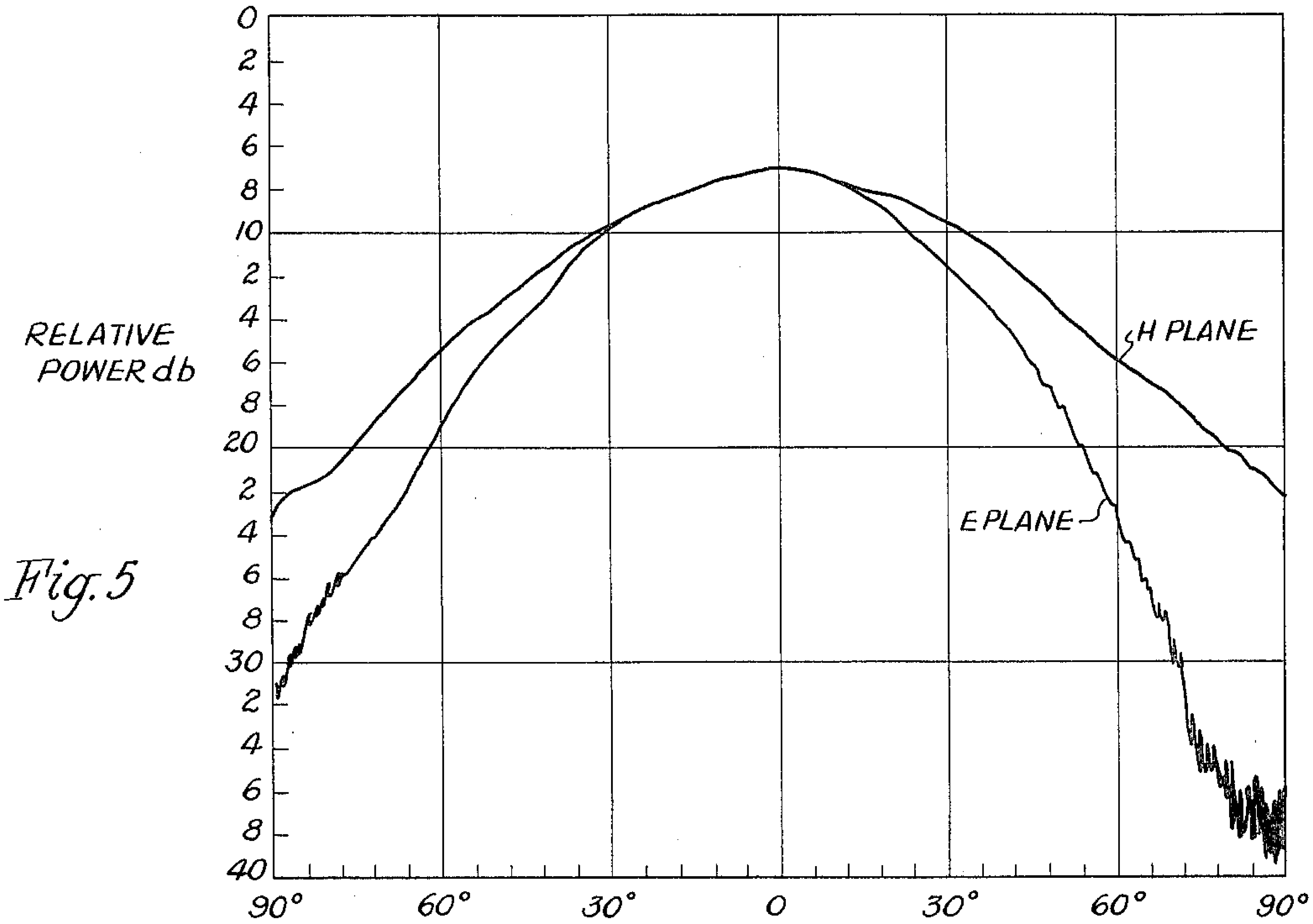

Fig. 5

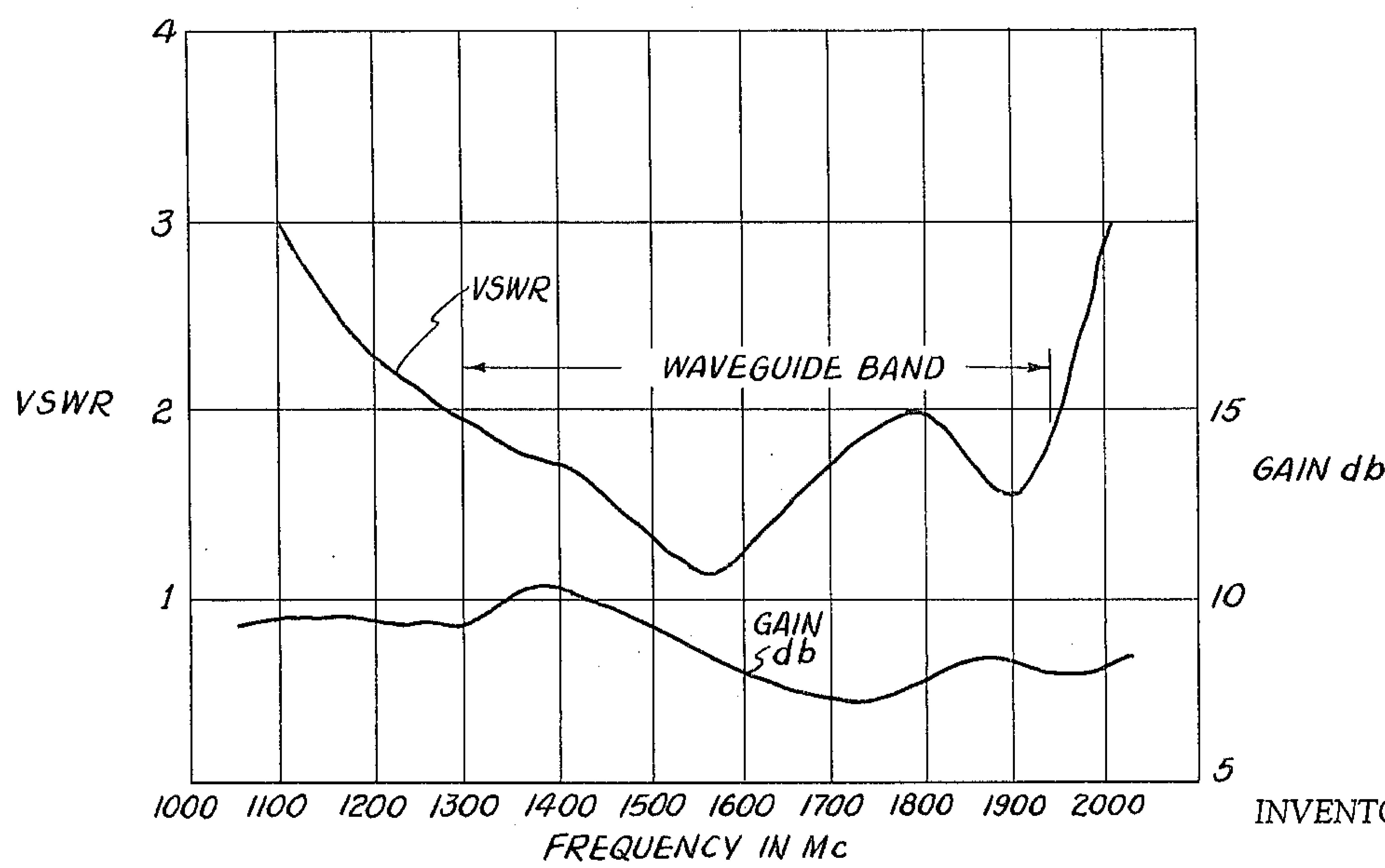

Fig. 4

INVENTOR

Kenneth S. Kelleher

BY

Glenn S. Ovrevik

AGENT

3,239,838

DIPOLE ANTENNA MOUNTED IN OPEN-FACED RESONANT CAVITY

Kenneth S. Kelleher, 1115 Marine Drive, Alexandria, Va.

Filed May 29, 1963, Ser. No. 284,197
5 Claims. (Cl. 343—789)

This invention relates in general to antenna devices and in particular to antennas of the cavity variety and suitable for flush mount installation.

A wide variety of antennas such as corner reflectors, horn assemblies, end fire arrays, etc. are available for use in VHF/UHF radio communication and electronic detection systems. While these prior art antennas have widespread utility in many commercial and/or military applications, it is generally recognized that they are each characterized by design limitations which often greatly restrict or deter their use in applications other than those for which they are specifically designed. For example, corner reflectors and end fire arrays frequently will leave something to be desired in the front to back response area. In addition, the radiation patterns of such antenna installations are often troubled by interference due to surroundings. Likewise, the basic structural configuration of horn assemblies prohibits their use in many applications where a flush mount design having minimum drag is a critical requirement.

In flush mount applications slot antennas incorporating dipole elements have been employed with some degree of success insofar as drag is concerned. However, present known cavity antennas of this variety have recognized problems of their own. In addition to matching complexities, this type of antenna heretofore has necessitated a relatively deep cavity, generally at least one-quarter wavelength in depth. As a consequence of this relatively wide spacing between the radiating element and the reflecting surface, the radiation characteristics have been less than adequate for many applications. To improve performance various cavity loading techniques embodying dielectrics, metallic posts, etc. have been employed to minimize depth but this complicates fabrication, greatly increases frequency sensitivity as well, and, thus, seriously limits antenna applicability. As an alternative, multiple radiator element designs have been employed but this modification has merely contributed to the complexities of the basic matching problem and the frequency sensitivity problem as well.

It will be appreciated that a compact antenna suitable for VHF/UHF use having radiation characteristics comparable to those of an electromagnetic horn but without the excessive bulk of prior art antennas is needed and would be welcomed as a substantial advancement of the art. Accordingly:

It is an object of this invention to provide a cavity antenna having substantially the radiation characteristics of an electromagnetic horn.

It is another object of this invention to provide a cavity antenna useful in applications requiring a substantially clean radiation pattern irrespective of surrounding discontinuities.

It is an additional object of this invention to provide an antenna which, when used as an illuminating radiator, provides an incident field with minimum flucuation due to reflections.

It is a further object of this invention to provide an antenna which is highly suitable for antenna test range purposes.

It is still another object of this invention to provide a cavity antenna which is useful in linearly polarized wave energy applications and is adaptable to circularly polarized wave energy applications.

It is another object of this invention to provide a rigid lightweight antenna which may be designed for use at frequency ranges over a wide frequency spectrum.

It is still another object of this invention to provide a rigid lightweight antenna which affords minimum drag in high velocity applications.

It is a further object of this invention to provide an antenna of the cavity variety suitable for use as a transmitting and/or receiving antenna.

It is an additional object of this invention to provide an antenna of the cavity variety which may be utilized as a single unit and may be dapted for module use in a multiple unit array.

It is also an object of this invention to provide a cavity antenna of minimum depth suitable for mounting on relatively long booms or the like.

Other objects of this invention will become apparent upon a more comprehensive understanding of the device of this invention for which reference is had to the following specification and drawings wherein:

FIGURE 1 is a pictorial showing in perspective of one embodiment of this invention.

FIGURE 2 is a side view cross-sectional showing of the FIGURE 1 embodiment of this invention.

FIGURE 3 is a front view diagramatic showing of the FIGURE 1 embodiment of this invention.

FIGURE 4 is a graphic presentation of typical voltage standing wave ratio and gain characteristics for the embodiment of FIGURE 1.

FIGURE 5 is a graphic presentation of a typical radiation pattern for the embodiment of FIGURE 1.

Briefly, this invention provides a novel antenna of minimum depth having substantially the same characteristics as antennas of the box horn variety. In the illustrated embodiment an open faced shallow cavity and a flat dipole radiator element, which is disposed substantially within the plane of the open face, are employed to provide the advantageous result. In this embodiment, the dipole is coaxially fed by a select impedance matching arrangement.

Referring now to the drawings:

FIGURE 1 depicts a typical VHF/UHF embodiment of this invention, which might be utilized in the 1120–1700 mc. range, for example, wherein a metallic resonant cavity **11** having an open front face is utilized in conjunction with a dipole element of the printed circuit variety indicated at **12**. In the exemplary embodiment of FIGURE 1 the flat dipole element **12** is disposed substantially in the center of the open face of the cavity and in substantially parallel relation with respect to the back-reflecting surface **11A** of the cavity **11**.

The dipole element in the exemplary embodiment of FIGURE 1 includes a winged section, indicated at **12A**, and a base section indicated at **12B**, which are symmetrically disposed about a selected center plane, indicated at **20**, in substantially perpendicular relation with respect to back reflecting surface **11A** of the cavity **11**. A relatively narrow slot, a nonconductive region disposed substantially within the center plane, divides the winged section **12A** into two $\frac{1}{4}\lambda$ portions and extends into the base section **12B** to form a U shaped section thereof. The narrow slot, indicated at **12C**, is slightly enlarged within the base section area for impedance matching purposes. It is understood, of course, that the general enlargement of the slot and the exact configuration depicted in the drawing are of particular significance in the select impedance matching means described hereinafter but may be altered in accordance with other impedance matching techniques, as required.

A coaxial transmission line having center conductor **13** and an outer conductor **14** is employed to feed the dipole element **12** with outer conductor **14** connector to the dipole element at its base and with the center conductor **13** electrically extended in the form of a U indicated at **15**. It will be noted that the plane of the U indicated at **15** also is in substantially parallel relation with the flat dipole element **12** and the back reflecting surface of the cavity **11**. It will be appreciated that the portion of the extended center conductor **13**, which is indicated at **15**, serves as an impedance matching means in this embodiment of the invention and affords a highly satisfactory energy interconnection between the unbalanced transmission line and the balaced dipole radiator.

As illustrated in FIGURE 1, the resonant cavity may be of square configuration with the two width dimensions substantially $n\lambda$ at the center operating frequency of the antenna, where n is an integer. In the 1120–1700 embodiment, for example, the cavity might be a seven (7) inch square cavity and the depth of the cavity might be three-fourth (¾) inch. It will be appreciated that resonant cavity configurations other than square are within the purview of this disclosure and may be employed in accordance with the teaching herein. For purposes of simplicity in illustration, however, the detailed description of this invention will be directed to the square cavity embodiment.

In the cross-sectional showing of FIGURE 2, the dipole **12** and the impedance matching means indicated at **15** are depicted as having the same thickness as the support member **16**. While the thickness of the impedance matching means and the dipole radiator are not critical and this size relation might be suitable for many applications of the device of this invention, it will be appreciated that both the impedance matching means indicated at **15** and the dipole **12** may be thin conductive films such as derived by simple printed circuit etching techniques. Alternatively, metallic foil having thickness substantially less than the support member **16** may be employed. A radome, indicated at **17**, which may be of any material suitable for the efficient transmission of electromagnetic wave energy, generally dielectric of the variety commonly referred to as glass laminate, is shown covering the open face of the cavity **11**. It will be appreciated, of course, that the radome **17** is not essential to the device of this invention and may be deleted without significant alteration of performance, as desired. For example, in applications where the antenna is not subject to abusive environmental effects or is otherwise housed in defense thereagainst, the radome **17** may be omitted.

In a typical case, the cavity **11** might be formed of aluminum by a conventional deep drawing process, if desired, and might have a thickness 0.102 after drawing. It has been found that some curvature of the corners is permissible and for purposes of fabrication and other purposes, as well, may be preferred. One-half inch radius on the corners of the open face and a one-fourth inch spherical inside radius on the other corners has been found to be acceptable. In accordance with common practice in the art the formed cavity may be plated, as necessary.

After assembly of the several component parts, the cavity **12** may be filled with conventional four pounds/cubic foot foam in the area indicated at **18** by means of the port **19**. It will be appreciated that foam in the area indicated at **18** is not essential to the device of this invention and is employed merely for support and/or spacing purposes, as may be needed in selected applications. Indeed, the area indicated at **18** preferably contains an air dielectric and any foam used should have substantially the same wave propagation characteristics as an air medium so as to avoid "loading" the resonant cavity to any degree.

For the exemplary embodiment of FIGURE 1, it has been found that the optimum spacing between the flat dipole **12**, which is disposed substantially in the plane of the open face of the resonant cavity, and the back reflect-

ing surface of the cavity is $\frac{1}{10}\lambda$ (wavelength) at the center operating frequency of the antenna.

FIGURE 3 is further illustrative of the basic embodiment of this invention. In this front view diagrammatic showing, a simple dipole is centered within the cavity at a $\frac{1}{10}\lambda$ spacing with respect to the back reflecting surface. It will be seen that the restricted cavity insures that the first order and the third order modes are in phase at the aperture and produce a resultant aperture field which is substantially uniform in the "H" plane. In the orthogonal plane, the proximity of the back reflecting surface of the cavity, which effectively serves as a ground plane, insures a uniform excitation across the aperture.

FIGURE 4 is a typical data plotting for the embodiment of FIGURE 1 wherein voltage standing wave ratio (VSWR) and gain are plotted as a function of frequency.

It is readily evident from these characteristic curves that the antenna of this invention has effectively overcome the frequency sensitivity problem common to the conventional cavity antenna. In addition, it will be noted that the gain level of the antenna of this invention is substantially greater than that of a box horn antenna of comparable aperture. Indeed, it has been found that the antenna of this invention has a gain level equal to or better than the gain level of a flare modified box horn of comparable aperture. Obviously, the gain of the antenna of this invention is vastly superior to that of other cavity or slot antennas.

Likewise, FIGURE 5 is a graphic showing of the radiation pattern for the embodiment of FIGURE 1 in both the "E" and "H" planes which indicates the inherent center lobe directivity of the disclosed embodiment is comparable to that of a conventional box horn. Moreover, it will be noted that this radiation pattern is free of the generally detrimental side lobes which are commonly associated with the conventional box horn.

In essence, it will be appreciated that the characteristic curves of FIGURES 3, 4 and 5 are indicative of a close similarity between the performance characteristics of a box horn antenna and the antenna of the present invention. In both instances energy is disposed in selected types of field configurations. For example, FIGURE 3 shows the fundamental mode with its cosine amplitude distribution and the third order mode with three half cycles of a sinusoidal-field configuration. These aperture fields are identical to those of the box horn.

It has been found that the antenna of this invention may be utilized as a single unit, in cooperative pairs, such as transmitting and receiving antennas on opposite wings of an aircraft, and in closely mounted multiple unit arrays to obtain a wider angle of coverage, for example.

It is understood, of course, that this invention is not restricted to the illustrated embodiment. In particular, resonant cavity configurations other than rectangular may be employed, the impedance matching means may be disposed on either side of the dipole radiator element, and other coupling techniques may be employed in various modifications for selected purposes.

Moreover, the device of this invention is not restricted to the frequency range of the exemplary embodiment. Indeed, it has been found that the antenna of this invention may be adapted to operate anywhere within the frequency range of 125 mc. to 7050 mc. It is understood, of course, that the last said frequency limits are arbitrary and these limits, likewise, are not to be considered restrictive to the invention.

Further, it is understood that the particular flat dipole disclosed in FIGURE 1 may be altered in accordance with well established practice in the art. For example, a webbed configuration might be utilized for the winged section of the dipole or the dipole winged section might constitute a mesh surface, if desired.

In addition, it is understood that this invention is not restricted to antennas embodying substantially solid metallic cavities as illustrated in the embodiment of FIG-

URE 1 and that any resonant cavity construction including simulated reflecting surfaces and impervious wire such mesh surfaces may be utilized when advantageous.

It will be appreciated that the compact, flat and lightweight features of the antenna of this invention, in particular, are ideally suited for multimodule antenna arrays. For example, in space satellite applications and portable ground installation applications, as well, it may be desirable to employ an expandible antenna array. In such instances, antenna modules constructed in accordance with this invention might be interconnected to permit folding and/or unfolding as required in the particular application.

In emphasis, the antenna of this invention is vastly superior to the conventional VHF/UHF antennas such as corner reflectors and end fire arrays, not only in size reduction, but also in improved side lobe levels and in front to back response. Because it provides a cleaner radiation pattern, the antenna is particularly ideal for use on antenna test ranges. As an illuminating radiator, it provides an incident field with minimum fluctuation due to reflections. As a gain standard, the antenna of this invention has all the data-reproducibility of the conventional horn. It is easily mounted so that its pattern is completely independent of its surroundings. In view of its compact size and light weight, it has been found to be particularly useful for polarization measurements where it is necessary to mount the illuminating source on a horizontal-axis rotator disposed at some height above the ground.

Finally, it is understood that this invention is to be limited only by the scope of the claims appended hereto.

What is claimed is:

1. A wideband antenna structure for use in a selected frequency range comprising

an open-faced resonant cavity having a planar back reflecting surface,

said cavity being substantially rectangular in cross section perpendicular to its radiating axis and having a depth of $\lambda/10$ and a width of $n\lambda$, where λ is the wavelength at the resonant frequency and n is an integer,

dielectric means disposed across the openfaced portion of said cavity, said dielectric means being substantially transparent to the transmission of electromagnetic wave energy,

dipole radiator means symmetrically disposed on one surface of said dielectric means at a distance substantially $\lambda/10$ from said planar back reflecting surface,

said dipole radiator means being formed of a conductive foil,

transmission line means, and

impedance matching means connecting said transmission line means to said dipole radiator means,

said impedance matching means including an energy feed member disposed on the opposite surface of said dielectric means from said dipole radiator means.

2. An antenna structure as defined in claim 1 wherein said dipole radiator comprises a base section and a substantially one-half λ winged section of conductive material with a non-conductive area dividing said winged section into substantially one-quarter λ portions and extending into said base section to form a U shaped section.

3. An antenna structure as defined in claim 1 wherein said energy feed member is a substantially U shaped member.

4. An antenna structure as defined in claim 3 wherein said wave energy transmission line is a coaxial transmission line, said U shaped energy feed member is electrically connected to the center conductor of said coaxial transmission line and said base section of said dipole radiator is connected to the outer conductor of said coaxial transmission line.

5. A wideband antenna structure for use in a selected frequency range comprising

an open-faced resonant cavity having a planar back reflecting surface,

said cavity being substantially rectangular in cross-section perpendicular to its radiating axis and having a depth of $\lambda/10$ and a width of $n\lambda$, where λ is the wavelength at the resonant frequency and n is an integer,

dipole radiator means mounted within said cavity at a distance substantially $\lambda/10$ from said planar back reflecting surface,

said dipole radiator means including a base portion which is substantially U shaped,

transmission line means, and

impedance matching means connecting said transmission line means to said dipole radiator means,

said impedance matching means including an energy feed member disposed on the opposite surface of said dielectric means from said dipole radiator means,

said energy feed member being substantially U shaped.

References Cited by the Examiner

UNITED STATES PATENTS

2,636,987	4/1953	Dorne	343—789
2,972,147	2/1961	Wilkinson	343—708
2,990,547	6/1961	McDougal	343—795

OTHER REFERENCES

Thourel, The Antenna, translated by Banting, Chapman and Hall Ltd., London, 1960, (page 327 relied on).

HERMAN KARL SAALBACH, *Primary Examiner.*

ELI LIEBERMAN, *Examiner.*

L. ALLAHUT, *Assistant Examiner.*